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COMPOSITION OF SOME ALBERTA PEATS

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University of Alberta

A THESIS
submitted to the University of Alberta
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the degree of
MASTER OF SCIENCE

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COMPOSITION OF SOME ALBERTA PEATS

K. H. Walker

INTRODUCTION

Bog or "muskeg" in Western Canada covers vast areas estimated at over twenty millions of acres. A glance at almost any Northern Alberta soil survey map shows large areas of muskeg.

Since peat is chiefly organic matter its formation is due to an accumulation of plant residues. Climatic factors are principally responsible for this accumulation, and thus can be considered important in the development of our extensive peat areas.

The saturation of the muskeg or bog with water produces anaerobic conditions which, according to Waksman and Stevens (35) do not prevent the growth of certain water-loving plants, but are unfavorable for the development of many micro-organisms such as fungi, actinomyces, and aerobic bacteria which would otherwise decompose the organic matter. The remaining facultative, and anaerobic bacteria are capable of attacking only certain organic complexes leaving others to accumulate.

Alberta peats are often comparatively raw or undecomposed. Many bogs have from two to three feet of light colored, mossy peat, some having as much as six feet in which

the structure of the various plant residues is easily observed; the apparent specific gravity is low, and the cellulose content high (21). This condition is probably due to the long period in which the bogs are frozen each year, during which time the activity of decomposing micro-organisms is very greatly reduced or completely prevented. It is not only during the winter season that the bog is frozen, for the excellent insulative properties of raw peat protect the frozen underlayers until midsummer; thus cold or frozen temperatures prevail for a large part of the year. Plants growing at the surface are not so greatly affected by this condition. In addition, acid conditions (below a pH of 4 in some of our bogs) also retard the development of many organic matter decomposing bacteria and actinomyces; thus an accumulation of raw peat is favored.

HISTORICAL

Probably the greatest interest in peat has centered about its fuel and industrial uses, the European development of which is ably discussed in a book by Hausding (12). Haanel (10) has traced the commercial projects and government experiments concerned with peat fuel manufacture in Ontario since the beginning of this century.

Peat lands, from an agricultural standpoint, have been rather unsuccessfully dealt with in Europe for centuries. They have always been marginal or sub-marginal lands upon which

which the inhabitants, in most cases, eked out a poor living. The usual method of the "squatter" occupants was to burn off a small acreage and farm it for a few years until the available plant foods, liberated by the burning, were nearly exhausted. Then they moved on. Again, in about thirty years, if the burning had been shallow, the original depth of peat would build up, after which time, it would once more be burned and occupied. This crude, inefficient burning method is practically abandoned in Europe now. The more successful modern way is to apply the needed commercial fertilizer (K, P, N, or lime) as required, and sand is often added to improve the physical condition of the peat.

REVIEW OF LITERATURE

Newton (21) has found that some of our Alberta acid peats (highmoor) have a greater percentage of cellulose than our lime (lowmoor) ones. The cellulose content of Alberta peat is comparatively greater than that of peat in most other countries (34). His analyses also show less cellulose but more lignin in the lower horizons of the profiles than in the surface ones.

Analyses (2) of a Minnesota peat bog show an average organic matter content of 87.7 percent, nitrogen 2.68 percent, lime 2.59 percent, phosphorus pentoxide 0.25 percent and potassium oxide 0.07 percent. Florida Everglades peats (9) vary from 1.4 to 2.7 percent nitrogen; from 0.40 to 0.47

percent phosphorus pentoxide; and from 0.037 to 0.048 percent potassium. Analyses made by Bedford (5 p. 524) of Winterburn, Alberta, peat are as follows:

Analyses of Peat Profile

Verticle Formation	Depth	Nitrogen %	Calcium %	Water %
Fairly dark color, Partially decomposed.	0"-7"	1.31	.71	79.11
Light colored, Raw peat.	7"-11"	.95	1.22	90.96
Darker in color than top layer.	11"-23"	1.80	3.20	86.30

The samples for the above analyses were obtained from a shallower part of the bog than those of the writer. A comparison of these results with analyses of Winterburn peat given later in this paper shows variations obtainable within different parts of the same bog, but even greater differences have been found by other investigators (17). Bedford also found thirty-one parts per million of nitrate nitrogen in an Alberta peat.

Variations between the horizons of a peat profile are shown by the analysis of Shutt and Wright (28) who found the surface layer lowest in lime, nitrogen and potash; but highest in phosphorus. They also found greatest acidity in the surface horizon.

Waksman and Starkey (38) state that in the presence of an abundance of undecomposed plant residues, artificial fertilizers increase the activity of bacteria considerably. Working with soil, these men found that a o.5 percent

application of potassium acid phosphate nearly doubled the bacterial population. Their results (38, table XI) from a soil of pH 4.6 show a large increase of bacteria as a result of a lime application. A further increase to over double the bacterial numbers of the check plot was obtained by the addition of mineral fertilizer and ammonium sulphate to a limed plot.

Pot experiments carried out by Newton and Paul (22) on Alberta peat showed that the application of fertilizers tended to increase the number of bacteria. A combination of nitrogen, potassium and phosphorus salts doubled, and in some cases tripled, the numbers. They also found that an application of complete fertilizer soon increased the percentage of nitrate nitrogen considerably. Vandecaveye (33) found that the addition of superphosphate, of sodium nitrate or of lime did not materially increase the number of micro-organisms in peat; whereas the work of Shunk (27) showed that decided increases of both bacteria and nitrate nitrogen resulted from additions of lime. These conflicting results are possibly due to the great variation found in different peats.

Waksman and Purvis (36) found an abundant population, principally bacterial, in all depths of peat profiles with the greatest number where the greatest decomposition had taken place. They thus conclude that bacteria are chiefly responsible for peat formation and transformation.

Various kinds of organic matter, added to clay loam soil, greatly improve its physical condition and increase yields of grass and for this purpose peat was found to be the

most permanent form of organic matter (30). Also when added to sandy soils it imparts a cohesiveness or "body" which reduces excessive leaching or evaporation. Page (26) further illustrates the value of organic matter by a comparison of two fields at Rothamsted both of which received the same amount of fertilizers over a period of years, one in the form of mineral fertilizer and the other as barnyard manure. The soil of the latter plot contains on an average five percent more moisture than the former, and is in a far better state of tilth. He advises that the effects of colloidal humus must be carefully distinguished from those of strawy undecomposed plant residues which if applied to a sandy soil are harmful. Experiments to show soil improvements by the addition of peat have also been done by Dachnowski-Stokes (7) who found that the moisture holding capacity of clay soil was raised from 42.1 to 104.6 percent after an equal volume of mossy peat had been added.

The San Joaquin peat used by Doughty (8) requires the application of "large amounts of phosphatic fertilizers and of these applications the major portion is immediately withdrawn from solution." He concluded that precipitation as iron, aluminum and calcium phosphates caused the removal of the phosphate from solution. Support of the precipitation removal is indicated by the work of McCool (19) who found that peat deposits containing a high soluble salt content fixed more phosphorus than those containing a low soluble salt content or than those which had had their soluble salts leached out.

Odynski (23) found that from forty to fifty percent of the phosphorus in the surface layer of Alberta soils is organic

and as such is probably relatively unavailable until the organic matter decomposes to liberate the phosphate ion. Since many of our peats contain over ninety percent organic matter one would reasonably suppose that most of the phosphorus they contain is in the organic form. Thus availability of phosphorus probably depends to a great extent upon the rate of decomposition of the peat. Moisture content was found to have a marked influence upon decomposition (37), with optimum moisture giving the greatest rate. Drying and then re-moistening peat greatly stimulated its decomposition.

Oats is the best grain crop for peat according to a comparison made by the University of Minnesota of a number of crops (13). Additional valuable information regarding the practical farming of peat lands in Scotland is contained in bulletins by Ogg (24), and the establishment of an improved pasture on peat is described by Clouston (6). Peat drainage and cultivation problems are ably discussed by Alway (1) and a section in a bulletin (39) by the Soils Department of the University of Alberta deals with peat.

TOPOGRAPHICAL AND BOTANICAL SKETCH

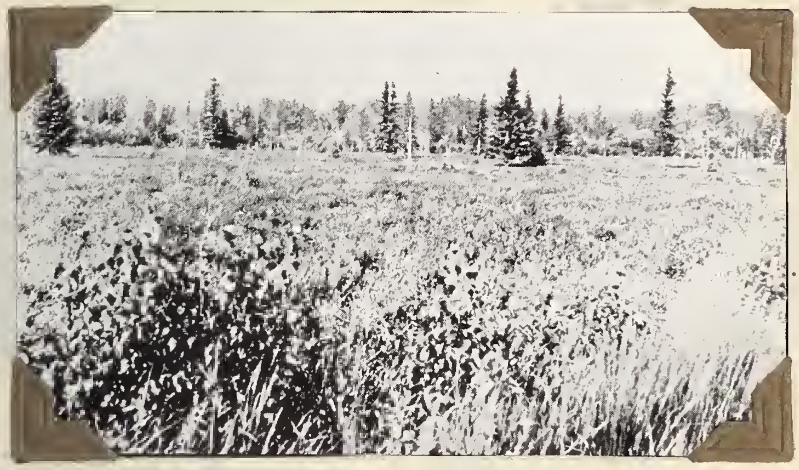

Fig. I.--Muskeg area. (From Univ. of Alta. Bull. No. 20: Soil Survey of St. Anne Sheet.)

A muskeg area is generally level as shown in the accompanying photograph (Fig. I) but the immediate surface usually presents a rough and uneven appearance caused by sphagnum mounds or semi-rotted logs. Very often in the spring the bog presents a flooded appearance with water showing among the mounds or even submerging them. Many muskegs are marginal to small sloughs and to permanent lakes; good pictures of such muskegs were taken by Lewis, Dowding and Moss (Fig. II).

Usually the open water is calcareous, although on the adjoining muskeg acid conditions may prevail. Fairly thick forests of spruce (Picea mariana), larch (Larix lariciana), and birch (Betula papyrifera) (17) may also be seen on some muskegs.

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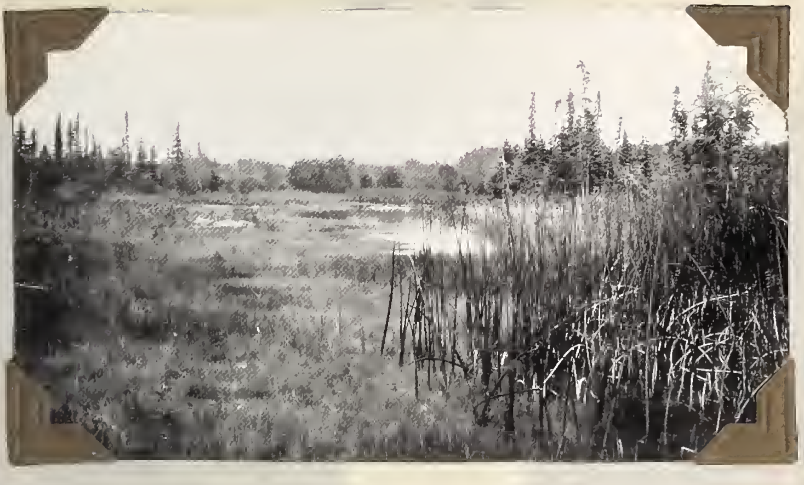

Fig. 17.--Muskeg marginal to a slough.
(From Lewis, Dowding, and Moss.
Journal of Ecology, Vol. XVI no. 1)

The chief plant whose remains accumulate to form our peat is sphagnum moss. Other plants inhabiting Alberta muskegs are: *Ledum groenlandicum* and *L. latifolium* (see plants growing on the peat in the profile photographs below) *Polytrichum commune*, *Vaccinium canadense* and *V. vitis idaea* (northern or low bush cranberry); to these may be added monocotyledonous sedges and grasses such as *Carex aquatilis* and *Scirpus sp.* occupying the wetter parts of the bog.

SAMPLE DESCRIPTIONS

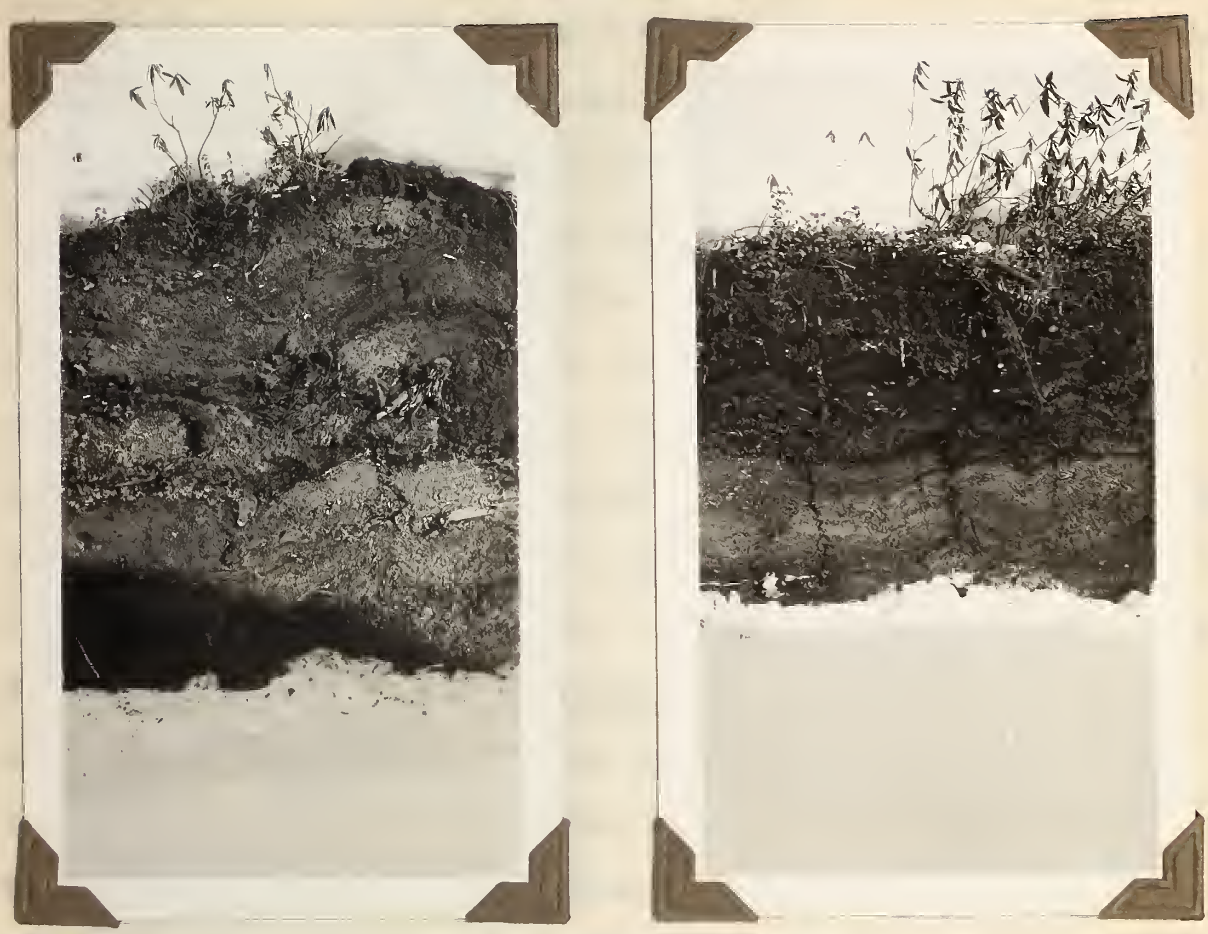

Fig. III Winterburn Peat Profiles

The preceding pictures (Fig. III) are typical of Alberta peat profiles.

In most muskegs the peat is from three to seven feet deep and of laminated formation. As a rule the upper layers are mossy, light colored and undecomposed; while the lower horizons are darker, more compact and of more decomposed material. However, there are exceptions to this rule, in which rather raw peat underlies fairly well decomposed material, as for example, the Carvel and Vimy profiles.

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Thirty-nine samples, representing the different profile layers of twelve bogs within seventy miles of Edmonton, were selected for the work reported in this paper. Most of the muskegs were in their natural state, the only cultivated one being on H. McLaughlin's farm, about a mile west of Spruce Grove. The Carnwood and Genesee Road acid bogs are in the partially leached transitional soil belt. Grass grows on the Duffield and Carvel muskegs to a greater extent than on the others, which are chiefly covered with sphagnum and Ledum. The western end of the Stony Plain bog is quite thickly wooded with spruce, whereas the eastern end is more open or lightly wooded with shrubs such as willow (Salix candida). The Winterburn muskeg is fairly open, carrying only a few small, scattered spruce trees; samples were taken near the excavations of Mosstex Ltd., Edmonton. The Nestow muskegs are small and lie between, what appears to be, fine sand dunes.

A brief description of the various samples is given in table I. In this table degree of decomposition, arranged in ascending order, is: raw, slightly decomposed, partially decomposed, semi-decomposed and decomposed. The bits of wood referred to in many samples are about the size of coarse sawdust discolored to a fawn or a brown and partly decomposed. A peat which is partly decomposed but consists principally of moss in which the thalus form is still distinct is referred to as having an open mossy structure and an open coarse structure if there is much roots, grass and Ledum in addition to the moss. The state of disintergration (structure) is arranged thus: open coarse, open mossy, open spongy, laminated, granular and crumbly.

Table I

Description of Peat Samples

Bog & Profile Location	Sample no.	Depth	Color	State of Decomposition	Structure	Remarks
25, 49, 1,	1.	0"-16"	light fawn	raw	open mossy	typical Sphagnum peat
w. of 5th	2.	16"-30"	fawn	partial	laminated	dark earthy streaks
	3.	30"-45"	variegated	semi-decomp.	finely gran.	bits of twigs & leaves
	4.	45"-60"	dark brown	decomposed	granular	apparent sp. gr. 0.36
	5.	below 60"	mottle-grey		finely gran.	silty mineral loam
½ mile east	6.	0"-24"	light fawn	raw	open spongy	apparent sp. gr. 0.15
of Carnwood	7.	24"-50"	brown	semi-decomp.	crumbly	30% bits of wood
along the	8.	0"-16"	light fawn	raw-slight	open mossy	similar to no. 1
Genesee Road	9.	below 16"	fawn	partial	laminated	acid field test
1 mile north	10.	0"-14"	fawn	slight	open spongy	40% bits of wood
of Duffield	11.	14"-30"	dark fawn	partial	crumbly	25% bits of wood
	12.	below 30"	brown	semi-decomp.	crumbly	apparent sp. gr. 0.36
3 miles N.W.	13.	0"-12"	fawn	partial	open grassy	bits of wood & roots
of Carvel	14.	12"-30"	dark fawn	semi-decomp.	open spongy	
	15.	below 30"	light fawn	partial	open mossy	similar to no. 1
Stony Plain	16.	0"-12"	light fawn	raw	open mossy	Ledum & roots
(west end)	17.	12"-24"	vari. fawn	slight	laminated	little wood or roots
	18.	24"-42"	fawn	partial	granular	some bits of wood
	19.	42"-48"	brown	decomposed	crumbly	some decomp. wood

Table I (Continued)

Description of Peat Samples

Bog & Profile Location	Sample no.	Depth	Color	State of Decomposition	Structure	Remarks
Stony Plain east end	20.	0"-6"	var. fawn	partial	open coarse	much grass, roots, Ledum
	21.	6"-24"	dark fawn	semi-decomp.	laminated	less fibrous than no. 20
	22.	24"-48"	brown	decomposed	crumbly	20% part decomp. wood
1 mile east Winterburn	23.	0"-6"	light fawn	slight	open coarse	grass, roots & Ledum
	24.	6"-30"	fawn	partial	part lamin.	salt incrustations
	25.	30"-42"	dark brown	decomposed	crumbly	25% bits of wood
	26.	42"-48"	blue black		puddled	mineral clay
Spruce Grove McLaughlin's farm	27.	0"-14"	red brown	decomposed	coarse gran.	30% decomposed wood
	28.	14"-24"	red brown	decomposed	coarse gran.	apparent sp. gr. 0.40
	29.	below 24"	grey		lumpy	mineral clay
1 mile west of Vimy	30.	0"-20"	light fawn	raw	open porous	fine plant roots
	31.	20"-34"	brown	semi-decomp.	granular	10% wood, 10% clay
	32.	34"-42"	mottle-fawn	partial	coarse crumbly	30% wood
	33.	42"-48"	grey	min. clay	coarse gran.	apparent sp. gr. 1.33
½ mile north of Nestow	34.	0"-10"	fawn	slight	fibrous mossy	similar to no. 23
	35.	10"-24"	brown	decomposed	granular	25% bits wood & charcoal
	36.	below 24"	grey		granular	mineral fine sand
Pickardville	37.	0"-20"	light fawn	raw	fibrous mossy	apparent sp. gr. 0.06
	38.	20"-50"	fawn	partial	laminated	10% wood, 10% dark earth
	39.	50"-60"	var. brown	semi-decomp.	coarse gran.	10% wood

EXPERIMENTAL METHODS

A solution for a hydrogen ion concentration test was obtained by filling a 250 cc. beaker half full of peat and wetting with about 100 cc. of distilled water. The mass was stirred and allowed to stand for a few hours; then a 35-40 cc. sample for the pH test was squeezed out by fitting a smaller beaker over the peat. All the samples were tested by means of the quinhydrone potentiometer, the first fifteen in duplicate in order to check any differences between fresh and partially dried samples. The quinhydrone results were also checked by colorimetric pH readings.

Hygroscopic moisture was determined by subjecting the air-dry samples to a temperature of 110 degrees centigrade for at least two hours, after which they were re-weighed and the percentage of loss calculated. An approximate idea of the organic matter content was obtained by the loss on ignition method. The same samples were ignited slowly in a muffle furnace, at first only to 400 degrees centigrade, and cooled; then to assure complete oxidation the ash had to be moistened with a little dilute magnesium nitrate and kept at a temperature of 700 degrees for about two hours. Duplicate samples showed that the weight added to the ash by the dilute magnesium nitrate was negligible. The calcium and phosphorus compounds in the ash were next brought into solution by digesting with five cc. of dilute hydrochloric acid on a water bath for an hour; then some distilled water was added and the heating continued a

little longer. This solution, along with the undissolved ash, was washed into a hundred cc. volumetric flask and made up to volume. The flasks were allowed to stand a few days before aliquots were removed for calcium and phosphorus determinations.

Calcium was determined by the official oxalate method (3) titrating against standard potassium permanganate.

Phosphorus was determined by the colorimetric method according to the modification developed by Truog (32). A few additional samples were ashed with calcium acetate to check the magnesium nitrate fusion method, as it was desirable to use the latter method so that both calcium and phosphorus could be determined in aliquots from the one sample; however, care must be used with the nitrate fusion to avoid spattering in its early stages. Twenty-five cc. aliquots were removed from the 200 cc. volumetric flasks and placed in 100 cc. volumetric flasks. Stannous chloride was found to be a somewhat better reducing agent than amino-naphthol sulfonic acid, which occasionally produced an interfering white precipitate. Correct acidity and the removal of any interfering iron, as shown by Truog, are of the greatest importance if the proper development of blue is to be obtained. The color of the unknown was read against that of a standard by means of Nessler tubes.

The Gunning Hibbard modification of the Kjeldahl method was used for the determination of nitrogen in 0.5 gram samples of peat.

The low potassium content of peat makes it necessary to use a fairly large sample of from 5 to 10 grams of peat.

This was moistened with water to which a little sulphuric or hydrochloric acid had been added to assist in holding organic potassium as the salt. The sample was ashed slowly over a Meker burner, and the water helped to retard the rate of ignition. After partial charring, ignition was completed in the muffle furnace at 550 degrees centigrade for two hours. Oxidation by sulphuric acid in Kjeldahl flasks as in a nitrogen determination was tried, but this method was unsatisfactory in these experiments.

The potassium salts were leached out of the ash by six or seven portions of hot water, filtered into a one hundred cc. volumetric flask and made up to volume. Potassium was determined from 25 cc. aliquots by the gravimetric platinic chloride method (14), and from other aliquots by the more rapid permanganate titration of the potassium sodium cobalti-nitrite salt (16) as modified by N. J. Volk of the University of Wisconsin. A number of known potassium solutions were determined by the latter method which consistently gave results approximately ten percent low. This was taken into consideration when calculating percentages of potassium in the peat. The potassium sodium cobalti-nitrite precipitate is so fine that difficulty was experienced in preventing it from running through the gooch crucible. This trouble was eliminated by fitting a small piece of acid washed filter paper in the bottom of the crucible and using a thick asbestos mat. After filtration the paper can be kept out of the permanganate solution until the end point is approached as in the calcium oxalate titration. Blanks taking two drops of the 0.1 N

potassium permanganate solution (from 2 to 5 percent of the unknowns) were obtained. A colorimetric adaption of the cobalti-nitrite method (20) was tried, but colors faded too rapidly. Possibly more work with this method would perfect it for use on peat analysis.

A sodium acid tartrate method (41) gave good results upon determining a known potassium salt solution, but when the method was applied to peat ash extractions faulty precipitates were formed.

The following series of ten pots was made up in triplicate, and duplicates were planted to Peatland Barley in order to determine the effects of nitrogen, phosphorus, potassium, lime and combinations of these on the growth of plants in peat. An outline of the experiment is as follows:

		Rate or Ratio	Amount per crock
Pot no. 1	Check or control		
" " 2	Ammonium Sulphate	200 lbs/ acre	.48 grams
" " 3	Triple Superphos.	400 " "	.96 "
" " 4	Potassium Sulphate	200 " "	.48 "
" " 5	No. 2 and No. 3	approx. ratio NH_3: P_2O_5:: 1 : 3	
" " 6	" 2 " " 4	" " NH_3: K_2O :: 1 : 2	
" " 7	" 3 " " 4	" " P_2O_5: K_2O :: 3 : 2	
" " 8	" 2, no. 3 & no. 4	" " NH_3:P_2O_5:K_2O :: 1:3:2	
" " 9	Calcium Carbonate	2.5 tons/acre	12 grams
" " 10	No. 8 and no. 9		

Finely pulverized, raw Winterburn peat (see description of samples no. 23 and no. 24) was used for all the pots,

and the various fertilizers were thoroughly mixed in the upper half of each.

Nitrates were determined on the unplanted series by the phenol di-sulphonic acid method as modified by Harper (11). For this determination twenty-five grams of peat, obtained by three borings with a soil auger in each pot, were weighed into shaker bottles. Re-shaking the supernatant liquid with carbon black removed interfering discoloration from the organic matter. Nessler tubes proved to be better than the colorimeter for reading the rather pale yellow developed by those samples low in nitrates. The greater thickness of solution used in the Nessler tubes gave a depth of yellow in the 0.5 parts per million nitrate nitrogen standard which is more easily and accurately matched than the paler colors shown by the shallow depths of solution used in the colorimeter. The Nessler tube readings were checked, in those samples in which the yellow was sufficiently intense, by colorimetric readings.

The cultural plate method was employed for determining the bacterial numbers. Thirty gram moist samples were taken with the soil auger as in the nitrate sampling, and shaken with two hundred cc. of sterile water. A one to one hundred thousand dilution was made and all samples plated out the same day. The medium used for total counts was asparagin mannitol agar of the following composition (31):

Agar		15.0 grams
Dipotassium phosphate	(K_2HPO_4)	1.0 "
Potassium nitrate	(KNO_3)	.5 "
Magnesium sulphate	($MgSO_4 . 7 H_2O$)	.2 "
Calcium chloride	($CaCl_2$)	.1 "
Sodium chloride	($NaCl$)	.1 "
Ferric chloride	($FeCl_3 . 6 H_2O$)	trace
Asparagin	($C_4H_8N_2O_3$)	.5 gm.
Mannitol		1.0 "
Water		1,000 cc.

Bacteria plated on this medium do not develop excessively large, overlapping colonies.

RESULTS OF ANALYSIS AND EXPERIMENTS

The results, obtained from this investigation of peat composition, will be discussed under the following headings:

1. Hydrogen ion concentration
2. Moisture and organic matter
3. Calcium content
4. Phosphorus content
5. Total nitrogen
6. Potassium content
7. Pot experiments
8. Nitrates
9. Bacterial counts

1. Hydrogen Ion Concentration.

These determinations are given in table II.

Table II

pH Readings of Some Alberta Peats

Method of Det. - Condition of Sample ---------		Quinhydrone	Quinhydrone	Colorimetric	
		Fresh & Moist	Partially dried	Fresh	Average
Profile	Sample no.				
Sec. 25, 49, 1, w. of 5th.	1.	3.75	3.8	4.0	3.9
	2.	4.1	4.0	4.6	4.2
	3.	5.5	4.5	5.4	5.1
	4.	5.9	5.1	5.7	5.6
	5.	5.3	5.7	---	5.5
Carnwood	6.	4.0	4.0	4.8	4.3
	7.	4.6	3.9	5.4	4.7
Genesee Road	8.	4.1	3.9	---	4.0
	9.	4.6	4.5	---	4.5
Duffield	10.	4.5	4.3	---	4.4
	11.	4.5	4.6	---	4.5
	12.	4.8	5.5	---	5.1
Carvel	13.	6.0	6.3	---	6.1
	14.	6.3	6.1	---	6.2
	15.	6.5	5.9	---	6.2

The remaining samples became partially dried in the laboratory and were tested by the quinhydrone potentiometer only.

Profile	Sample no.	pH
Stony Plain (west end)	16.	5.8
	17.	5.5
	18.	5.6
	19.	5.7
Stony Plain (east end)	20.	7.1
	21.	7.1
	22.	6.4
Winterburn	23.	5.3
	24.	6.4
	25.	7.0
	26.	7.3

Profile	Sample no.	pH
Spruce Grove McLaughlin's farm	27.	7.3
	28.	6.4
	29.	7.3
Vimy	30.	3.8
	31.	6.4
	32.	5.8
	33.	7.3
Nestow	34.	4.5
	35.	5.4
	36.	5.8
Pickardville	37.	3.8
	38.	4.4
	39.	5.1

Although the indicators and standards for the colorimetric method were freshly prepared, readings were consistently higher from this method than those from the quinhydrone potentiometer. The personal factor in comparing shades of color, and light variations are greater in a colorimetric method than is desirable. Partial drying in the laboratory did not greatly affect the pH as may be seen by comparing the two quinhydrone series in the first fifteen samples.

It will be noted that variation of pH is considerable, with some samples as acid as pH 3.8 and others slightly on the alkaline side at pH 7.3 (table II). These results are comparable to those of Dachnowski-Stokes (7) who found a pH range of from 3.5 to 7.1 in many samples of peat from various parts of the United States.

The lower profiles are less acid than the upper ones in practically all cases. For example, in the Winterburn profile the surface sample no. 23 has a pH of 5.3 and a lower horizon no. 25 a pH of 7.0. Shutt and Wright (28), analysing peat from Caledonia Springs, Ontario, report pH 3.94 in the surface horizon gradually rising through four horizons to pH 6.78 at a depth of from six to seven feet.

2. Hygroscopic Moisture and Organic Matter.

Hygroscopic moisture determined by drying at 110 degrees centigrade and organic matter content obtained by the ignition of peats are shown in table III.

Table III

Analyses of Alberta Peats

Profile Location	Sample no.	pH	Hygro. Water %	Organic Matter %	Ca %	P %	N %
			Percentages, water free basis				
25, 49, 1, w. of 5th.	1.	3.9	8.5	98.4	.89	.041	.61
	2.	4.2	9.6	95.7	1.51	.028	.71
	3.	5.1	10.3	91.2	2.54	.035	1.73
	4.	5.6	9.2	90.5	2.01	.043	2.25
	5.	5.5	2.7	----	.83	----	.32
Carnwood	6.	4.3	8.3	98.1	1.06	.067	.82
	7.	4.7	8.3	94.4	2.46	.066	1.64
Genesee Road	8.	4.0	9.6	96.6	2.16	.055	.69
	9.	4.5	8.7	95.7	1.92	.024	.55
Duffield	10.	4.4	8.7	91.7	1.88	.062	1.65
	11.	4.5	9.7	93.3	2.7	.033	1.35
	12.	5.1	9.3	91.9	2.15	.038	2.90
Carvel	13.	6.1	12.2	86.9	4.30	.096	1.32
	14.	6.2	12.3	86.7	4.5	.075	1.69
	15.	6.2	11.5	88.1	4.25	.051	.95
Stony Plain West	16.	5.8	6.4	64.5	1.30	.075	.74
	17.	5.5	9.8	94.0	2.55	.046	1.04
	18.	5.6	11.2	91.0	4.40	.033	.96
	19.	5.7	11.9	86.0	5.55	.040	1.17

Table III (Continued)

Analyses of Alberta Peats

			Percentages, water free basis				
Profile Location	Sample no.	pH	Hygro. Water %	Organic Matter %	Ca %	P %	N %
Stony Plain East	20.	7.1	7.9	70.0	2.50	.078	.96
	21.	7.1	11.5	88.0	5.90	.103	1.63
	22.	6.4	10.6	85.3	3.07	.086	2.23
Winterburn	23.	5.3	8.0	87.0	1.38	.083	1.14
	24.	6.4	10.1	93.5	3.12	.046	.91
	25.	7.0	11.3	85.0	4.85	.073	1.86
	26.	7.3	3.7	----	----	----	.28
Spruce Grove McLaughlin's farm	27.	7.3	12.7	82.8	5.73	.123	1.92
	28.	6.4	12.8	79.8	6.67	.087	1.98
	29.	7.3	2.5	----	----	----	.16
Vimy	30.	3.8	8.2	97.0	.76	.027	.46
	31.	6.4	9.2	52.1	4.53	.110	1.14
	32.	5.8	10.5	88.0	4.24	.015	1.20
	33.	7.3	3.4	----	----	----	.31
Nestow	34.	4.5	8.8	89.2	1.32	.023	.76
	35.	5.4	10.6	77.3	1.34	.149	1.54
	36.	5.8	.7	----	----	----	.04
Pickardville	37.	3.8	8.3	93.5	.66	.054	.62
	38.	4.4	8.5	92.0	.78	.030	.94
	39.	5.1	8.6	89.8	1.21	.044	2.28

Table III (Continued)

Comparative Peat Analyses

Perecentages, water free basis

Profile Location	Depth	pH	Hygro. Water %	Organic Matter %	Ca %	P %	N %	K %
Caledonia	0"-8"	3.9	7.8	89.3	.34	.045	1.67	.020
Springs, near	2'-3'	5.3	8.6	87.3	.95	.025	2.09	.036
Ottawa, Ont.	5'	6.0	8.8	86.6	.95	.025	2.69	.030
(28)	6'-7'	6.8	10.8	80.9	1.93	.028	2.51	.050
Golden Valley, Minn. (2)				87.7	1.85	.109	2.70	.060
Rice Lake, Minn. (2)				94.0	.22	.070	1.70	.030
Forest Heights, Minn. (2)				79.5	.72	.166	2.90	.070
Fen Peat, Scotland (19)					2.50	.109	2.50	.100
Moor Peat, Scotland (19)					.35	.044	1.20	.050

Comparative Mineral Soil Analyses

Profile Location	pH	Hygro. Water %	Organic Matter %	Ca %	P %	N %	K %
Edmonton black loam (39)	6-7		12.0	.94	.100	.53	1.7
Alberta wooded soil (40)	6.2			.55	.060	.09	—

The high hygroscopic moisture content of peats (compare no. 35 to no. 36, a sand) is due to their natural absorptive and retentive nature. Air drying conditions in the laboratory during winter are particularly effective, as ordinary fuel peat contains from twenty-five to thirty percent moisture. The underlying mineral soils (nos. 5, 26, 33, 36) are decidedly lower in hygroscopic moisture than are the peats. Ignition does not give a very true picture of the organic matter content of a mineral soil owing to the formation of oxides, loss of water of hydration, loss of carbon dioxide, etc.; therefore, loss by ignition of the few mineral soils studied is not listed.

3. Calcium Content.

The percentages of calcium in the various samples of peat are given in table III.

As was to be expected, those profiles testing high in calcium are least acid (see table III); for example, sample no. 27, with the high calcium content of 5.73 percent, has a slightly alkaline pH of 7.3, whereas the low calcium samples are quite acid. However, the relationship between lime and acidity is not absolute, owing to biological variations resulting in the greater or smaller production of organic acids, and possibly other factors; consequently some of our peats which are fairly high in lime also test rather acid. Free calcium carbonate was tested for with acid but the only sample to show any appreciable effervescence was no. 27. One would thus expect no. 28, with its higher calcium content, to effervesce also but such was not the case. In this connection

reference to table I shows a pH of 7.3 for no. 27 and a lower pH 6.4 for no. 28 in spite of the higher calcium content. Evidently, little of its calcium is in the free lime state.

Which of these peats need liming? Tentative figures given by Alway (2) set 0.9 to 1.2 percent calcium peats as doubtfully requiring lime. If the lime content is from 0.6 to 0.9 percent then liming will likely be necessary, and if below 0.6 absolutely necessary, for most farm crops. Above a calcium content of 1.5 percent liming is not beneficial no matter what the acidity is. On this basis only two profiles, i.e. Vimy and Pickardville definitely require liming.

4. Phosphorus Content.

The percentages of phosphorus in some Alberta peats are shown in table III.

One is struck by the variation in the phosphorus content of our peats, and also by the considerable differences between horizons of many of the profiles. Analyses of a number of Minnesota bogs by Alway (2) also show wide variations of phosphorus content from 0.38 to 0.06 percent, which are somewhat higher percentages than those of the Alberta peats analysed. The same bulletin gives the following increases resulting from a four hundred pound application of acid phosphate per acre to the crops grown on the Golden Valley Experimental Field: oats, 48.5 bushels per acre; rye, 25 bushels per acre; and potatoes, 22 bushels per acre. This Golden Valley peat contains 0.109 percent phosphorus (see table III, Comparative analyses).

The phosphorus content of some of the better peat samples is similar to the 0.1 percent phosphorus typical of Alberta black soils (39), but most of the peats are low in phosphorus even on a weight basis (note samples no. 30 and no. 34).

The relationship between the state of decomposition and the phosphorus content of the peats is not definite; however, the analyses of many of the profiles indicates that the more decomposed horizons contain the lesser amounts of phosphorus. Such an indication is also shown by the analyses of Shutt and Wright (28) who report 0.102 percent phosphoric acid in the fibrous surface layer of an Ontario peat, 0.057 percent at two to three feet, and 0.057 percent at five feet where the peat was "very dark brown and does not show much fibre".

One would expect an increase of phosphorus with decomposition as occurs in the case of nitrogen and it is difficult to account for the decrease found in the decomposed horizons. Three possible reasons are suggested: First, acid conditions are common in the history of peat bogs and at pH 3-4 Doughty (8) has shown that practically all aluminum phosphate comes into solution, in which form it may be leached from the peat. Second, many bogs contain much calcium, and Doughty (8) found that in the presence of calcium over twice as much phosphate came into solution at a pH of 5.9 as at pH 7.1. Thus again, acid conditions in a bog cause the solution of phosphorus which may lead to its loss. Third, mineral soils may lose inorganic nitrogen compounds more readily than they lose

phosphates but in peat there is much organic nitrogen which may be relatively insoluble under field conditions. The increase of nitrogen from decomposition could also be due to a loss of the carbohydrate parts of peat, such as cellulose which Newton (21) has shown to decompose before nitrogenous organic compounds. Thus, during the centuries of bog formation, the slower decomposition of nitrogenous compounds has tended to raise the percentage of nitrogen in the lower, older parts of the bog.

No analyses for available phosphorus were made; however, since a large portion of soil phosphorus is held in organic combination (23 and 29), available phosphorus would depend upon the rate of decomposition of the peat, which is slow. Thus the available phosphorus content of our peats is probably low even where the total phosphorus is high.

5. Total Nitrogen.

The results of the nitrogen determinations are given in table III.

Most of our peats appear to be fairly rich from a nitrogen standpoint when compared to ordinary soils on a weight basis, but not so rich on a volume basis. For example, no. 4 is one of the highest, with 2.25 percent nitrogen and an apparent specific gravity of 0.384 (see sample description). Average Edmonton black loam has an apparent specific gravity of approximately 1, and 0.53 percent nitrogen (40). Thus on a volume basis assuming the black loam has 0.53 percent nitrogen, the peat sample no. 4 would have 0.86 percent nitrogen; but a less fertile one such as no. 37 would have only 0.037 percent nitrogen.

An increase of decomposition in the horizons of a profile (usually denoted by an increase of depth) is practically always accompanied by an increase in nitrogen content as will be seen from a study of table III. This is to be expected, as carbon is usually lost more rapidly, relatively, than nitrogen when organic matter with a wide carbon to nitrogen ratio is decomposed by micro-organisms. Similar results were obtained by Shutt and Wright (28).

It is interesting to note that the east end of the Stony Plain bog is considerably richer in both nitrogen and phosphorus than the west end.

6. Potassium Content.

Some difficulty was experienced in analysing peat for potassium. The results of analysis by two methods are given in table IV.

Bedford (4) found indications of "an apparent lack of potash in Alberta peats", a fact borne out by the following analyses in table IV. Compared to our mineral soils with a potassium content of 1.7 percent (39) the peat samples are very low in potassium. Reference to various analyses of peats, (table III, Comparative analyses) shows a range of potassium content from 0.02 to 0.10 percent.

Those profiles in which the surface peat is more undecomposed than the underlying layers may contain most potash in the least decomposed layer. Not enough analyses were made to establish this point and no references were found supporting it; in fact the Caledonia Springs profile (28) shows a fluctuating potassium

content in the four horizons, but a trend toward a slight increase of potash with increasing depth. However, in table IV the rawest, lightest colored, and most undecomposed of all the samples (no. 37) was highest in potassium.

Table IV

Potassium Content of Alberta Peats (water free basis)

Profile	Sample no.	Platinic-chloride Method	Cobalti-nitrite Method
25, 49, 1, w. of 5th.	1.	.---	.022
	2.	.029	.013
	3.	.032	.015
	4.	.030	.009
	5.	.---	.---
Carnwood	6.	.---	.057
	7.	.076	.055
Genesee Road	8.	.---	.083
	9.	.---	.124
Duffield	10.	.103	.162
	11.	.---	.042
	12.	.---	.007
Winterburn	23.	.---	.013
	24.	.---	.015
Pickardville	37.	.---	.233

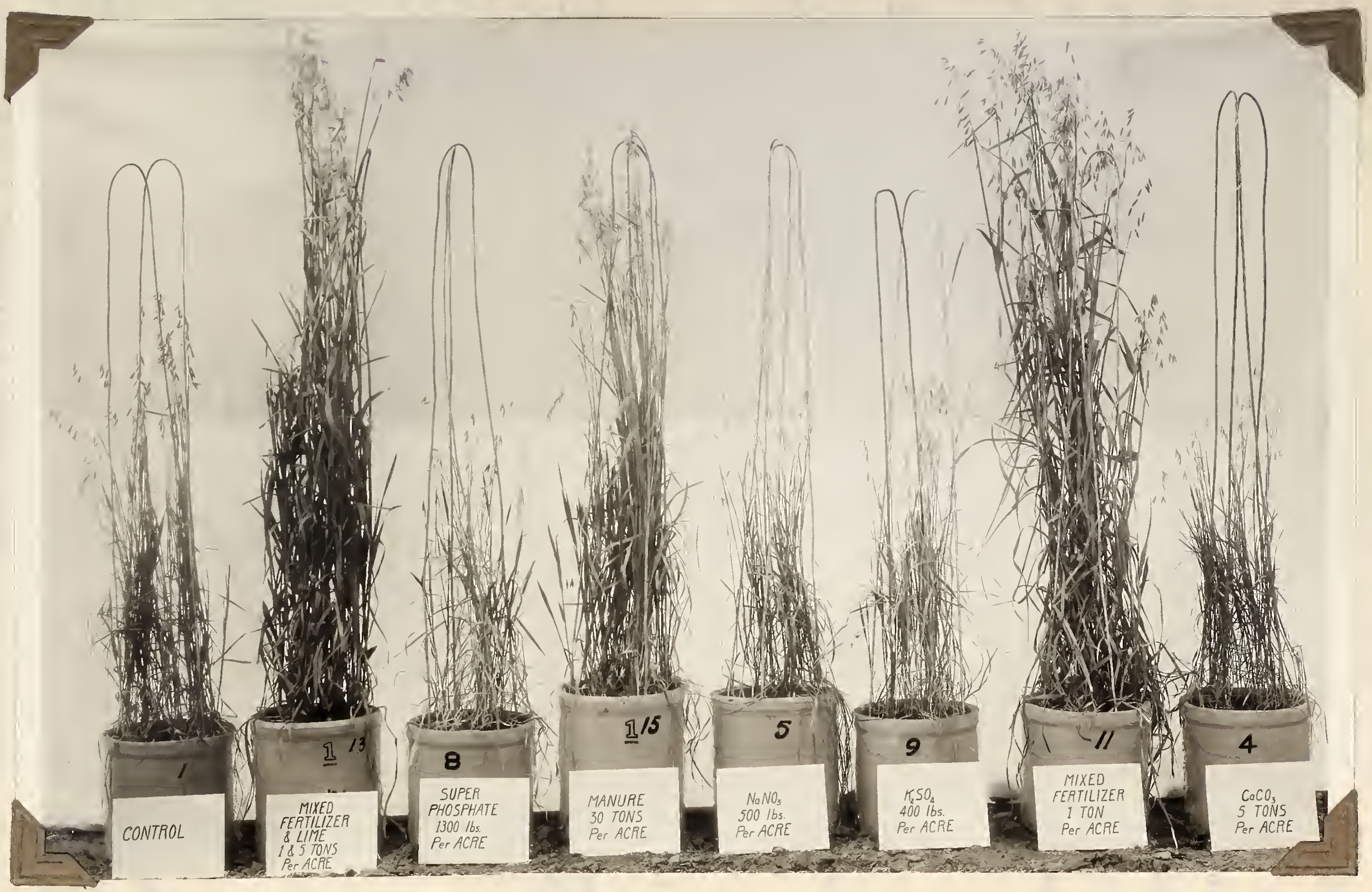
The agreement between the methods is poor, but the amounts of potassium are small and thus the limits of error high for the methods used.

Many of the peats contain only enough potassium for ten or twelve crops providing all of it could be made available. This can be calculated as follows: the Carnwood peat with an average specific gravity of approximately 0.15 for the top two and a half feet would weigh about a million pounds. Thus 0.055 percent potassium in that sample would mean

approximately 550 pounds of potassium in one acre of Carnwood peat to a depth of thirty inches. Good grain crops require about fifty pounds of potassium per year. Potatoes on the Golden Valley peat (2) gave a greater response to potash than to phosphorus, the increase in yield for potassium fertilization being 62 bushels. Even more striking effects of potassium fertilization were obtained on the Momence field in Illinois (15) where corn has been grown almost continuously since 1902. For the first four years the average yield on the phosphate fertilized plot was 2.0 bushels, and 43.0 bushels on the potassium fertilized plot; in fact it was difficult to get much of a corn crop without applications of potash in some form or other. The peat at Momence is a well decomposed muck containing three to five times as much potassium as ours; consequently, good responses will probably follow from the application of potash to Alberta peats.

7. Pot Experiments.

Results similar to those obtained by Newton and Paul (Fig. IV) were expected from our pot tests but this experiment proved to be very disappointing. All the pots started off well and apparently healthy seedlings appeared six days after planting the peatland barley; about ten days later all pots except the outside four (control and complete fertilizer plus lime) became sickly and the tips of the leaves became feathery. More water was added to the moist peat, making it quite wet, but this did not seem to help matters. Some re-planting was done but the new seedlings did not fare any better than their


1
CONTROL
1 13
MIXED FERTILIZER & LIME 1 & 5 TONS Per ACRE
8
SUPER PHOSPHATE 1300 lbs. Per ACRE
1 15
MANURE 30 TONS Per ACRE
5
$NaNO_3$ 500 lbs. Per ACRE
9
K_2SO_4 400 lbs. Per ACRE
11
MIXED FERTILIZER 1 TON Per ACRE
4
$CaCO_3$ 5 TONS Per ACRE

Pot experiments by Newton and Paul, University of Alberta, 1931. (Stony Plain peat)

predecessors. About two months after the experiment was started, it was noticed that the peat was badly infested with little white maggots of the fungus gnat, a pest prevalent in the greenhouse. These seemed to be clustered about the seeds, roots and stems of the young barley plants and quite probably did considerable damage, because after the use of insecticides the few remaining plants revived. Unfortunately, there was not time to repeat this experiment.

8. Nitrates:

The nitrate nitrogen analyses, on a water free basis, are shown in table V.

Table V

Nitrate Nitrogen in Alberta Peats (parts per million)

Pot no.	Fertilizer Treatment	Incub. period 47 days	Incub. period 83 days	Incub. period 93 days
1.	Control	14.3	48.0	61.5
2.	N	36.5	211.0	262.0
3.	P	33.6	89.5	128.8
4.	K	55.4	206.0	116.3
5.	NP	48.0	93.6	174.2
6.	NK	83.8	196.5	188.3
7.	PK	50.5	48.5	71.0
8.	NPK	73.5	250.0	178.0
9.	$CaCO_3$	71.5	103.2	56.8
10.	$CaCO_3$NPK	114.5	202.0	197.5

The longer incubation periods of 83 and of 93 days gave a considerable increase in nitrate production over the shorter 47 day period. The increase of nitrates in the fertilized pots over those in the control is very marked. As would be expected, the addition of nitrogen in the form of ammonium sulphate stimulated nitrate production in the two longer incubation

periods. In the case of the 93 day period, the five pots highest in nitrate content were those which had been fertilized with ammonium sulphate. Newton (21) found in a cellulose fermentation experiment that the numbers of ammonifying bacteria, which are essential for nitrate production, increased with each additional "essential element" added. Soil nitrate content may fluctuate considerably from day to day and is influenced by moisture and other biological conditions. An endeavor was made to keep conditions uniform in all pots, but variation of these conditions was probably the cause of the rather unexpectedly low results obtained in the analyses of samples from pots number 7 and 9.

The wide carbon:nitrogen ratio of Winterburn peat such as 22:1 and 33:1 (5) would lead one to expect a smaller production of nitrates than those reported. Bedford obtained an increase from 35.5 to 41 parts per million nitrate nitrogen by an application of lime and nutrient salts after fourteen days incubation of a Winterburn peat. One reason for the unexpectedly high nitrate production may be that peat decomposes much slower than many other forms of organic matter (30) and as a result there may not be a large number of nitrogen consuming micro-organisms present. Thus forms of nitrogen such as ammonia, liberated by the slow decomposition of nitrogenous organic matter in peat, would be available for the formation of nitrates.

9. Bacteria.

BACTERIA PLATES (After six days' incubation)

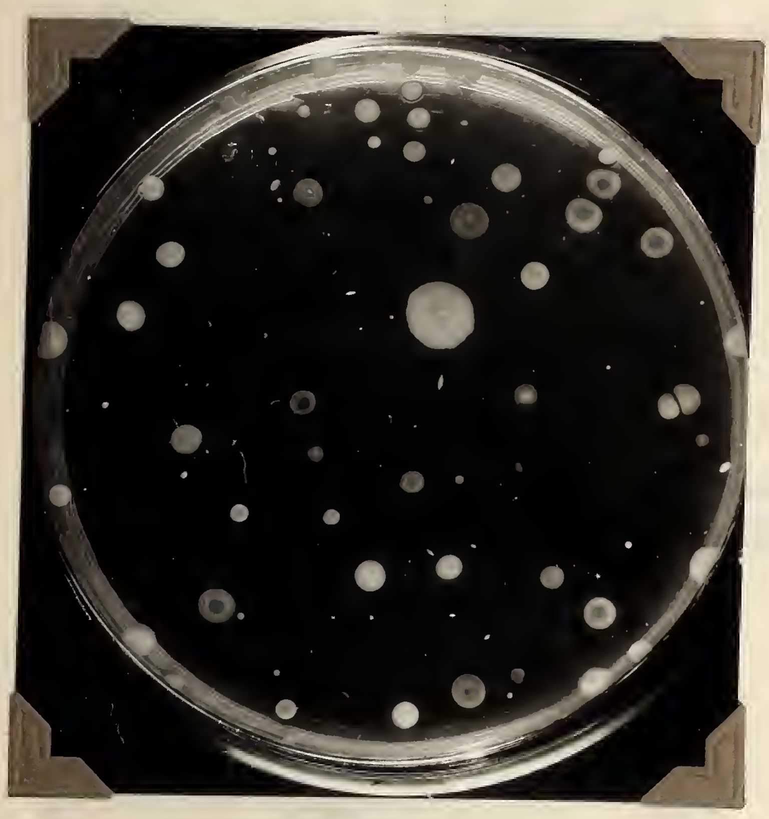


Figure V

Plated from the control pot of peat. (Numbers less than half Fig. VI)

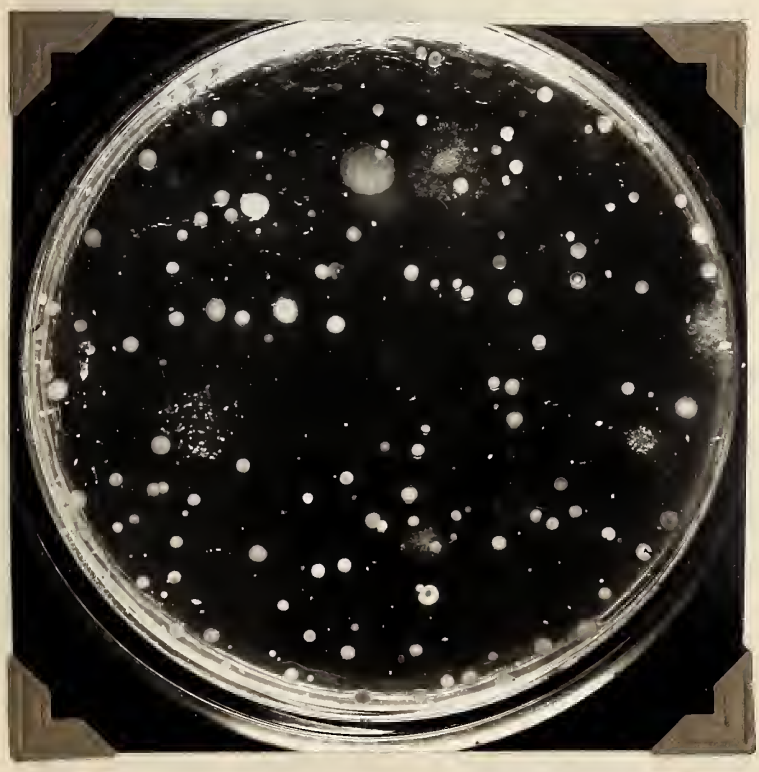


Figure VI

Plated from the lime and complete fertilizer pot of peat.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

The photographs (Figs. V and VI) show the differences in bacterial development under lime-fertilizer, and control conditions, although samples of the control tested a few days previously had shown an almost neutral pH of 6.7. The plates were counted and numbers of bacteria calculated as given in table VI.

Table VI

BACTERIA (Millions per gram of water free peat)

Pot no.	Fertilizer	Incubation period 52 days	Incubation period 83 days
1.	control	41	39.7
2.	N	113	65.0
3.	P	110	70.7
4.	K	86	66.5
5.	NP	126	87.5
6.	NK	132	72.5
7.	PK	106	81.0
8.	NPK	107.5	81.5
9.	$CaCO_3$	82	71.0
10.	NPK $CaCO_3$	132.5	84.0

A longer incubation period than 52 days does not seem to increase the bacterial numbers, as shown in table VI. A lime application (pots 1 and 9) approximately doubles the number of bacteria. As in the case of nitrates (table V) the number of bacteria in the fertilized pots, by comparison with the numbers of those in the control, is more than double. The complete fertilizer plus lime pot gave one of the highest counts which is similar to the results obtained by Newton (21) for a Carnwood peat. He obtained counts of twenty-nine million bacteria for his control and a maximum of seventy million in the culture containing the three fertilizer salts and lime after fifty days' incubation.

SUMMARY

A study has been made of thirty-nine samples representing twelve profiles of peat from the Edmonton district. Special attention was given to hydrogen ion concentration, moisture and organic matter, calcium, phosphorus, nitrogen, and potassium content. Pot experiments were conducted to determine effects of different fertilizers on nitrification and bacterial numbers in one of the peats. From this work the following facts or conclusions are obtained:

(1) The surface horizon of a peat may be as acid as pH 3.8 and the lower layers almost neutral or even a little alkaline. An increased pH value accompanied increased depth in most of the profiles studied. There is also considerable variation in hydrogen ion concentration between different bogs and even within the same bog.

(2) Hygroscopic moisture is usually from 6 to 12 percent higher in a peat than in a mineral soil; consequently optimum moisture conditions for the growth of plants in peats will be wetter than those in mineral soils.

(3) For the most part there is an association between high lime content, low acidity and medium or high amounts of total nitrogen. However, the European rule that lowmoor (high lime) peats are fertile, and highmoor (low lime and acid) peats infertile, cannot always be safely applied to our peat deposits.

(4) The highest lime content of 6.67 percent was found in a cultivated peat. In most of the profiles there is an increase of lime with an increase in depth.

(5) Phosphorus content is rather low in most peats. If the low apparent specific gravity is taken into account, it will be obvious that the amount of phosphorus or potassium within reach of an average root system would, in most cases, be very small.

(6) Total nitrogen in Alberta peats is, as a rule, fairly high; though probably not quite as great as in the nitrogenous peats of some other countries. The more decomposed layers have the higher nitrogen content; thus there is a larger percentage of nitrogen in the lower horizons than in the surface of most of the profiles. An examination of the Carvel profile did not show its lowest horizon to be as greatly decomposed as the layers above, and this bottom horizon has the lowest amount of both nitrogen and phosphorus in that profile. When the total nitrogen of peat is compared to that of Edmonton black loam on a volume basis, the amount is usually less than the nitrogen of the loam.

(7) Alberta peats, in common with many others, are low in potassium. A peat, such as that at Winterburn, contains only enough potassium in the upper thirty inches for from ten to twelve grain crops, providing all of it could be made available.

(8) An application of inorganic salts to some of the experimental pots more than doubled the bacterial numbers and approximately quadrupled the development of nitrate

nitrogen. A lime application at the rate of two and a half tons per acre raised bacterial numbers from approximately forty to eighty millions per gram and more than doubled nitrate content. However, when lime was applied in addition to fertilizer salts, the increase of bacteria and nitrate were no greater, in most cases, than with fertilizer salts alone.

(9) No definite relationship between the character of the peat deposits and that of the underlying material was established, but this relationship was not investigated in many cases.

(10) The classification of our peat areas will be very difficult, if not impossible, owing to the presence of many variables.

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BIBLIOGRAPHY

(1) ALWAY, F. J.
Report of the Golden Valley peat experimental fields.
Minn. Bull. no. 194 pg. 93, 1918.

(2) ALWAY, F. J.
Agricultural value and reclamation of Minnesota peat soils.
Univ. of Minn. Ag. Exp. Sta. Bull. 188 pg. 20, 1920.

(3) ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS
Official and tentative methods of analysis.
Chapt. 29 N sec. 11, Ca sec. 16 (3)

(4) BEDFORD, R. H.
Some biological and chemical activities of Alberta soils.
University of Alberta, unpublished M. Sc. Thesis, 1928.

(5) BEDFORD, R. H.
Decomposition of peat measured by carbon dioxide evolved.
Sc. Ag. Vol. IX no. 8, April, 1929.

(6) CLOUSTON, D.
Establishment of pasture on virgin peat.
Scottish Jour. Ag. Vol. XV no. 3, July, 1932.

(7) DACHNOWSKI-STOKES, A. P.
Grades of peat and muck for soil improvement.
U. S. D. A. Circular 290, 1933.

(8) DOUGHTY, J. L.
Fixation of phosphate by a peat soil.
Soil Sc. Vol. 29, no. 1 pp. 23-35, 1930.

(9) HAMMER, H. E.
Florida Everglades peat soils.
Soil Sc. Vol. 28, pp. 1-14.

(10) HAANEL, B. F.
Peat, its manufacture and uses.
Report of the Peat Committee, Dom. Dept. of Mines, 1925.

(11) HARPER, H. J.
Method for the determination of nitrates.
Jour. Ind. & Eng. Chem. (annal. sec.) 16 pg. 181, 1924.

(12) HAUSDING, A.
A handbook on the winning and utilization of peat.
Dept. of Sc. & Ind. Research His Majesty's Stationery office, London, Eng., 1921.

(13) HAYES, H. K., ARNY, A. C., WILSON, H. K., POWERS, LeROY
Crop investigations on peat lands.
Univ. of Minn. Ag. Exp. Sta. Bull. 292, 1932.

(14) HIBBARD, P. L.
Methods of chemical analysis
Detm. potassium as platinichloride, 10.12 Lindo-Gladding Method, 1923.

(15) HOPKINS, C.G., MOSIER, J.G., VAN ALSTINE, E., GARRETT, F.W.
Kankakee County soils.
Soil Report no. 13 Ag. Exp. Sta. Univ. of Ill., Urbana, 1916.

(16) KRAMER, B., TISDALL, F. F.
Potassium in blood.
Jour. Biol. Chem. 46 pg. 339, 1921.

(17) LEWIS, F. J., DOWDING, E. S.
The vegetation and retrogressive changes of peat areas ("muskegs") in Central Alberta.
Jour. of Ecology, Vol. XIV no. 2 August, 1926.

(18) LEWIS, F. J., DOWDING, E. S., MOSS, E. H.
Vegetation of Alberta II.
Jour. of Ecology, Vol. XVI no. 1

(19) McCOOL, M. M.
Peat and muck soils.
Mich. Sta. Quart. Bull. 3, no. 4 pp. 126, 1921.

(20) MORRIS AND GEIDEL
Method for potassium.
Plant Physiol. 8: 315-319, 1933.

(21) NEWTON, J. D.
A study of composition and utilization of Alberta peats.
(to be published) Ann. Applied Biol.

(22) NEWTON, J. D., PAUL, A. D.
Influence of various fertilizers on biological activity in Alberta peat soils.
Unpublished work for the National Res. council,
Univ. of Alta. Dept. of Soils, 1931.

(23) ODYNSKI, W.
Solubility and distribution of phosphorus in Alberta soils.
Univ. of Alta. M. Sc. Thesis, 1934.

(24) OGG, W. G.
Reclamation and cultivation of peat land in Lewis I & II
Scottish Jour. Ag. Vol. XIV no. I, April, 1931.
Scottish Jour. Ag. Vol. XV no. II, April, 1932.

(25) OGG, W. G.
Reclamation and cultivation of peat land in Northern Europe.
Scottish Jour. Ag. Vol. XII no. 1, pg. 6, Jan. 1929.

(26) PAGE, H. J.
The part played by organic matter in soil system.
Transact. of the Faraday Soc. Vol. 17, 2, 1922.

(27) SHUNK, I. V.
Microbiological activities in upland bog soil.
Soil Sc. Vol. 27 pp. 283-303, 1929.

(28) SHUTT, F. T., WRIGHT, L. E.
Peat, muck and mud deposits.
Dom. of Can. Dept. of Ag. Bull. no. 124 (new series), 1933.

(29) SNYDER, H.
Soils.
Minn. Ag. Exp. Sta. Bull. no. 41, pg. 30, 1895.

(30) SPRAGUE, H. B., MARRERO, J. F.
Value of organic matter for soils.
Soil Sc. 34: pp. 197-208.

(31) THORNTON, H. G.
On the development of a standard agar medium for counting soil bacteria, with especial regard to the repression of spreading colonies.
Ann. Applied Biol. 9: 241-274, 1922.

(32) TRUOG, E., MEYER, A. H.
Improvements in the Deniges Colorimetric Method for phosphorus.
Jour. Ind. & Chem. Eng. (anal. ed.) 1: 136-139, 1929.

(33) VANDECAVEYE, S. C.
Microbiological activities in peat.
Soil Sc. 33: 279-299, 1931.

(34) WAKSMAN, S. A., STEVENS, K. R.
Chemical composition of peat.
Soil Sc. 27: 271-281, 1929.

(35) WAKSMAN, S. A., STEVENS, K. R.
The role of micro-organisms in peat formation and decomposition.
Soil Sc. 28: 315-340, 1929.

(36) WAKSMAN, S. A., PURVIS, E. R.
Microbiological population of peat.
Soil Sc. 34: 95-109, 1932.

(37) WAKSMAN, S. A., PURVIS, E. R.
Influence of moisture on peat.
Soil Sc. Vol. 34, pp. 323-336, 1932.

(38) WAKSMAN, S. A., STARKEY, R. L.
The soil and the microbe.
John Wiley and Sons Inc. N. Y. pp. 67 and 222, 1931.

(39) WYATT, F. A., NEWTON, J. D., MATHER, T. H.
Soil survey of the St. Ann Sheet.
Univ. of Alta. Dept. of Extension Bull. no. 20, 1930.

(40) WYATT, F. A., NEWTON, J. D.
Wooded soils and their management.
Univ. of Alta. Dept. of Extension Bull. no. 21, 1932.

(41) __________
Volumetric method for determination of potassium.
Jour. Ind. & Eng. Chem. (anal. ed.) Vol. 3, no. 3,
July 15, 1931.

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